"Improvement of Environmental Conditions
(Water and Sanitation) in
Indigenous Communities"

GTZ-PAHO/WHO

Improved Stoves as a Key Intervention to Enhance Environmental Health in The Andes

Lima and Eschborn, 2005

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Regional Project:
Improving Environmental Conditions for the Indigenous Population
Agreement GTZ-PAHO/WHO.

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Preface

When we did the first home interviews in the Quechua-speaking community of Ayamachay as part of the GTZ-PAHO Project «Improvement of Environmental Conditions (Water and Sanitation) in Indigenous Communities», one of the most difficult tasks was interviewing the women when they were cooking: The interviewers could not cope with the smoke produced by the eucalyptus firewood to the point where they were coughing so hard that they had to leave the room.

It was obvious that this method of cooking bore no relation with the romantic image of movie stars gathered round an open fire in an elegant country resort.

Kitchens in rural Andean households are small rooms often without windows and with the walls and ceiling so blackened that it seems impossible to figure out what is in the pot. It is like cooking blind. If you touched the ceiling your hand most likely will stick to the accumulated soot. These conditions suggest that the housewives' lungs resemble those of chain-smokers. And not only they spend several hours a day cooking, but they do so accompanied by their youngest children.

The original purpose of the pilot project in Ayamachay was to improve the supply of drinking water, hygiene and sanitation. However, after seeing the conditions under which food is prepared health we decided to include the validation and construction of improved stoves that would eliminate indoor smoke and also promote the practice of boiling water while using less fuel. We quickly realized the size of this problem: about 40% of Peru´s population, that is about 9 million people, use firewood, charcoal, agricultural waste or animal dung as fuel on a daily basis. Statistics also indicate that respiratory illnesses are the most common diseases, above all among those who live in the highlands and in poverty. We asked ourselves if there was a relation?

To find out **José Humberto Bernilla Carlos,** an engineer who grew up in Ayamachay was appointed to develop the improved stoves presented in this publication. The «Inkawasi Stove» as the result of his efforts is called, was installed in more than 90% of households in the village of Ayamachay, which indicates a high degree of acceptance and satisfaction on the part of direct users.

In the Andes little research has been done considering health effects of smoke produced by burning firewood for cooking. It was therefore decided to carry out such investigation. **Dr. Roberto Accinelli Tanaka,** neumonologist of Peruvian Cayetano Heredia University, together with his team of physicians, demonstrated the relevance of this problem, which has been unjustly ignored for a long time.

Special thanks and acknowledgement is due to the people of Ayamachay-Inkawasi for their dedicated participation in every phase of the project, especially the assessment of impacts, which provided the research team with the results that form part of this document.

We would like to thank Mr. Bernilla and Dr. Accinelli, co-authors of this publication; as well as Mr. José Reto, Mrs. María Vasquez and Dr. Marcelo Korc (PAHO/WHO), and the institutions of the Local Working Group in Lambayeque (NGO CENTRO ECO, the Regional Government and the DISA of the Dept. of Lambayeque, the Provincial Municipality of Ferreñafe and others) for their support to this important project. In 2005, the NGO Centro ECO joined efforts with *Winrock International* to implement a stove dissemination project in the district of Inkawasi.

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Regional advisor, GTZ

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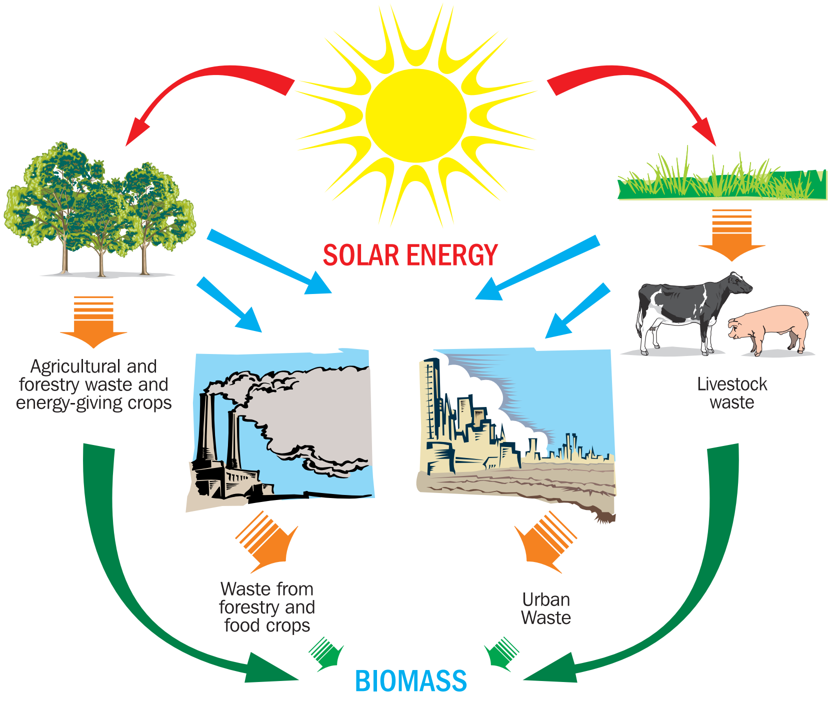
Implementation of Stove Project as a Key Intervention in the Improvement of Environmental Health in the Andes

I.- The relevance of this subject in Peru

Air pollution inside households is a public health problem. Figures from the World Health Organization show that this problem is responsible for approximately 1'849,000 deaths each year in developing countries. The World Bank also estimates that 400 million children and 700 million women are at risk because of exposure to contamination arising from the use of biomass for cooking and heating. Studies in Latin American countries such as Guatemala, Mexico, El Salvador and Peru, and Asian countries such as China, India and Thailand have found a relationship between high concentrations of contaminants in indoor-air generated by using wood and charcoal without a chimney and adverse effects on the health of people exposed to them, being the most vulnerable groups women and children under five years of age[1].

Figure 1:
Principal forms of biomass generation



[1] Comparative diagnosis of air quality inside homes in two indigenous communities in Peru

Biomass fuels

Biomass fuels are, in the simplest sense fuels of plant or animal origin, the most widely used biofuel being firewood, followed by charcoal, dung and crop waste.

Cooking on an open fire in the house is known to be the oldest technology used by humans and in many cases it is still the prevailing technology. In many developing countries the demand for domestic fuels amounts to more than half of the total demand for energy.

In Peru, firewood is used all over the country: coastal lowlands, Andean highlands and the Amazon Basin. In the Amazon Basin and the highlands it is the most important fuel for cooking food. It is also used in many rural industries, such as tea, coffee, charcoal and lime production, bakery and brick making. This demand has put a lot of pressure on forests. In the highlands, the use of trees as firewood for cooking exceeds all other alternative uses: manufacture of furniture and tools, construction, medicinal uses, forage, etc. It is estimated that of the 7 million inhabitants of the Peruvian highlands, some 4 million use biomass for cooking, as alternatives such as kerosene or gas are beyond their means. Nevertheless, it should be mentioned that the lack of trees and woodland in some areas of the high Andes makes firewood and other forest products a scarce resource; therefore, people use animal dung for

cooking their food. On the coast, firewood use as a domestic fuel is less, though it is common in the north, where wood is gathered from the dry forests[1]. In the cities, firewood supply usually is the result of illegal activities such as lumberjacking in protected areas, corruption and trafficking.

The traditional stoves consist of three stones or adobe bricks. They are very inefficient as they make use of only 10% to 15% of energy stored in the firewood. Furthermore, and especially because of the climate in the Andean regions, kitchens have minimal ventilation leading to severe exposure to smoke by those inside. The level of exposure to toxic substances deriving from the burning of biomass is ten or twenty times higher or even more, than the levels recommended by the World Health Organization[1].

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[2] Evaluation of the effect of biomass fuels on the respiratory apparatus in three rural communities in the Andes: Cutini Capilla (3850 m.a.s.l., Puno), Ayamachay and Uyshahuasi (2850 m.a.s.l., Lambayeque), Roberto Accinelli, Cecilia Yshii, Eduardo Córdova, Marita Sánchez-Sierra, Celia Pantoja, Jessica Carvajal, Cayetano Heredia Peruvian University, Lima, 2004

In Peru 30% of the total population lives in rural areas. According to INEI's National Household Survey 2001, 78.4% of this rural population is poor or extremely poor. This is expressed by inaccessibility, lack of hygiene, unhealthy living conditions, illiteracy, lack of sanitation, unavailability of technology, etc. In such places it is also traditional to use biomass fuels, which are an additional hazard to human health.

In Peru it can be said that the use of solid fuels is directly related to the level of poverty:

Table 1:
Population using Solid Fuels (Biomass)
by Geographical Area – 2002

Region		Percentage (%)
Coast	Urban	31.77
	Rural	87.96
Highlands	Urban	45.00
	Rural	76.22
Amazon Basin	Urban	61.82
	Rural	95.54
Metropolitan Lima		3.66
Urban Total		25.92
Rural Total		82.05
National Total		42.97

Source: INEI 2001.

Table 2:
Use of Solid Fuels (Biomass) by Poverty Level
1997, 2001 & 2002

Poverty level	Percentage (%)		
	1997	2001	2002
Extreme poverty	34.45	80.21	77.75
Poverty	28.36	51.28	46.03
Not poor	37.2	24.19	23.49
Total	39.22	45.75	42.97

Source: INEI 2001.

Concern about the use of wood as fuel concerns not only the impact on human health, but also the environment, since the use of wood has led to deforestation and, therefore, erosion and reduction in water sources: A report entitled «Experiences of the Fight against Desertification in Poor Semi-arid Zones of Latin America and the Caribbean», indicates that in the highlands of Peru there are serious problems of degradation affecting its fragile ecosystems, caused by using technologies that are inappropriate to the environment; it is estimated that the rate of deforestation in Peru is 220,000 Ha/year combined with very serious problems of erosion, since 72% of recorded severe erosion (5'800,000 Ha) is in the highlands. These reasons have led various institutions to implement programs to fight against deforestation and desertification, which include rational use of wood as fuel, and the employment of improved stoves in order to increase energy efficiency and therefore improve wood consumption[1].

II.-Effects on Human Health of Exposure to Indoor Biomass Combustion

Biomass fuels have always been used in Peru for preparing food. It was only 25 years ago that it was realized that they could cause respiratory problems. Women over 60 in the highlands were found to suffer chronic coughs and expectoration. Examination revealed wheezing and occasionally crepitus. Chest X-rays showed enlarged lung and bronchial dilatation. Spirometry tests showed a mixed pattern, with irreversible restrictions and obstructions. There was a common background to all this: they all cooked using wood during a lifetime.


Use of biomass fuel to prepare food

When experts from the Respiratory Laboratory of the «Highland Investigation Institute» of the Peruvian Cayetano Heredia University made these first observations, they thought they had discovered a new illness, as the symptoms were not described in the North-American and European medical reference books used in Peru at the time.

They were surprised to find that Restrepo at the Santa Clara Hospital in Santafe de Bogota, Colombia had already published the first work on this subject in 1980. This association had also been observed in Nepal, China, India, New Zealand and other developing countries. The problem is that research into problems affecting poor countries reaches other groups of developing countries only with difficulty and, in general, only after publication in scientific journals in developed countries.


The walls of this kitchen have been refurbished before implementing the Inkawasi Stove; the ceiling is black because of the soot accumulated.

Accinelli carried out the first work on exposure to wood smoke under guidance of Dr. Hever Kruger to

assess the magnitude of damage to the lungs using two groups of guinea pigs. In the highlands of Peru guinea pigs are traditionally raised in the kitchen near a three stone hearth. It was found that for guinea pigs raised in the kitchen, the proportion of weight of their lungs to total body weight was greater than for animals raised outside.

The use of fuel causes respiratory problems

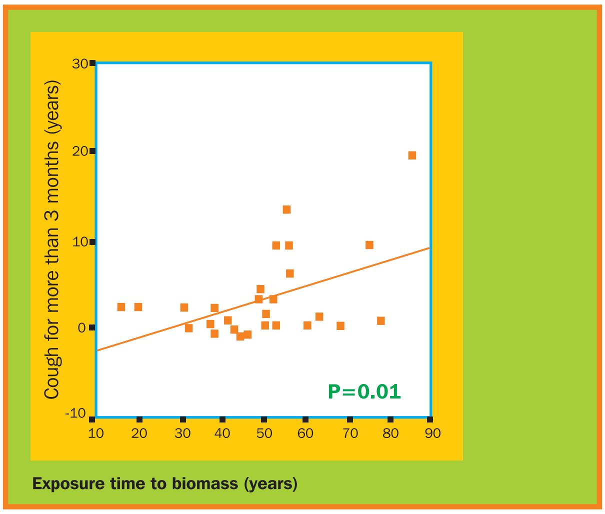
Furthermore, their lungs contained many black spots and stains. Microscopic examination showed a proliferation of glandular bronchial tumors, destruction of the alveolar septus (emphysema), anthracotic nodules and areas of proliferating fibroblast. Guinea pigs live for only 1 or 2 years and in this short time of exposition to wood smoke these changes occured to their lungs.

A number of the large contradictions in Peru are revealed by exposure to smoke from biomass fuels. It is a problem which usually affects the poorest and those living in rural areas. Studying the problem in the cities, as examined by Accinelli in Barranca and Tarma, it was found that in homes using biomass fuels there were more people per room compared to homes in which there was no exposure, indicating that poverty not only forces people to use biomass fuels but to live in overcrowded conditions. Curiously, the same study found that children exposed to biomass fuels spent more time in the house than children not exposed which further increases exposure.

Gender inequality can again be seen in the use of biomass fuels, as women are the most affected. In the GTZ and PAHO study carried out by Accinelli in the communities of Cutini Capilla in Puno, Ayamachay and Uyshahuasi in Inkawasi, Lambayeque it was found that women spent some 4 hours more in the house than men. They also spend a couple of hours more a day in the kitchen. Accinelli found that in two communities, one at sea level and the other 2,400 m.a.s.l., the maximum respiratory flow of women in both communities was significantly less than expected though this did not apply to the men, who were exposed for significantly fewer time.

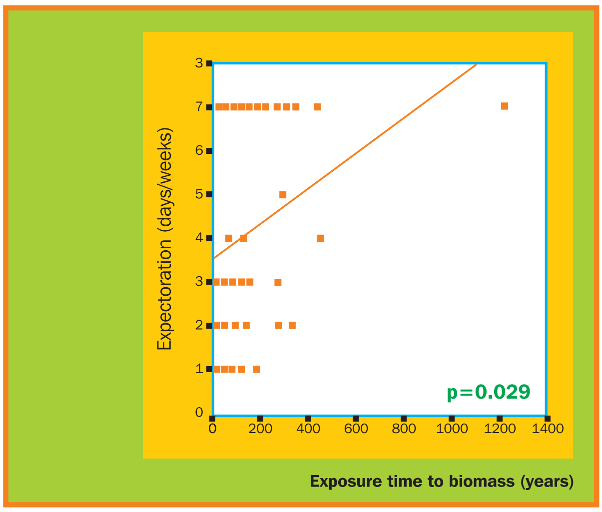
In the same study Accinelli found that respiratory problems increased with the number of years of exposure to biomass fuels. In a study in Cutini Capilla in Puno, Ayamachay and Uyshahuasi in Inkawasi, Lambayeque, a direct relationship was found between the number of years in which people suffered from a cough for more than three months and the number of years of exposure to biomass fuels. (Figure 2)

Fig. 2: Relationship between years of exposure to wood smoke and cough lasting more than 3



As the number of years of exposure to biomass fuels and the number of hours a person spends each day in the kitchen are important, both have been included in the exposure index, which is the product of the number of years by the number of hours. Accinelli found that in Cutini Capilla in Puno and in Ayamachay and Uyshahuasi in Inkawasi, Lambayeque that the higher the exposure index the more days of the week a person suffered from expectoration (Figure 3).

Fig. 3: Relationship between the wood smoke exposure index and the number of days a week a person suffered from expectoration



In the communities of Cutini Capilla in Puno, Ayamachay and Uyshahuasi in Inkawasi, Lambayeque, Accinelli found that 64.6% of women had had cough during the last two weeks while only 43.5% of men had the same symptoms ($p = 0.017$). Another very interesting finding was that women's leucocyte average (4,587.5) was above men's (4,569.3) ($p = 0.017$) indicating a greater inflammatory response associated with spending more time in contact with biomass fuels. It was also found that the more hours were spent in the kitchen the greater the number of leucocytes in the blood. (Figure 4)

Fig. 4: Relationship between the number of hours a day spent in the kitchen and the leucocyte count

It is known throughout the world that chronic bronchitis, defined as cough and expectoration for at least 3 months for two consecutive years, is caused by smoking tobacco. Accinelli found, through multistage conglomerate sampling, that 6.45% of those interviewed in Barranca were suffering from chronic bronchitis, whilst in Tarma the figure was 3.75%. But only one person admitted to smoking 5 cigarettes a day, too small a figure to be considered as a cause of chronic bronchitis. Neither had any of the interviewees previously suffered from tuberculosis or any significant respiratory illnesses. In

contrast, 58.7% and 83.12% of the inhabitants of Barranca and Tarma with chronic bronchitis said that they had been exposed to biomass smoke as children, figures that are higher than the 36.77% and 38.12% of those over 14 with this background. Accinelli also discovered this relationship between chronic bronchitis and exposure to biomass fuels during the early years of life among secondary school children and university students from Cuzco and Ayacucho, of whom rather more than 15% suffered from chronic bronchitis.

The same group from Cayetano Heredia Peruvian University studied 60 women with at least 30 years' exposure to biomass fuels, who did not smoke, had not suffered from TB and had not had chest surgery. Those who produced an abnormal chest X-ray had been exposed for longer to biomass fuels. But it is better to evaluate functional impairment than radiological evidence. Spirometric results revealed that 50% of these women had some form of spirometric abnormality.

Spirometry

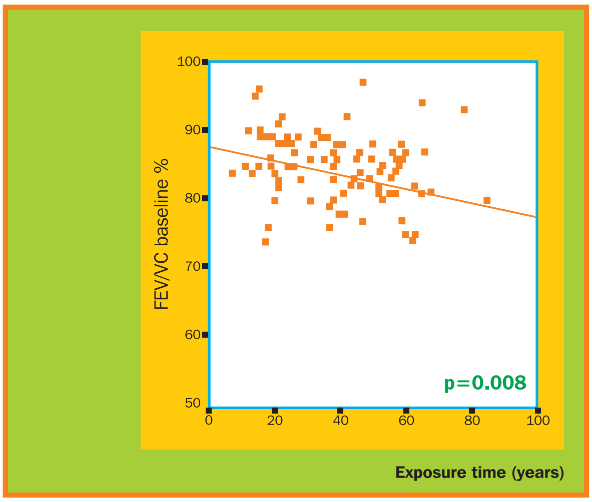
Spirometry measures the amount of air that a person can eliminate from the lungs after breathing in as deeply as possible.

The volume of air we exhale after filling the lungs to capacity is known as the vital capacity (VC). Linking this volume with the amount of time required to complete exhalation is called chronometric spirometry. Chronometric spirometry enables us to determine the amount of air exhaled in a given time, and we can find the gradient of the volume-time curve that is formed. People suffering from an illness that affects airways within the lungs (the trachea, bronchi and bronchiole) take longer to exhale completely. The quantity of air eliminated in the first second is known as the forced expiratory volume one (FEV1) and this is lower in, for example, a person suffering from asthma than in a healthy person. The gradient of the line joining the points corresponding to 25% and 75% of the vital capacity gives us the forced expiratory flow 25-75%. (FEF 25-75%). The way to differentiate between an illness that reduces the size of the lungs, which is known as a restrictive process, and one which affects the airways, known as an obstructive process, is to determine the ratio FEV1 / VC. When this ratio is less than 80% we can determine that the problem is an obstructive process.

A simple linear regression analysis produced a highly significant inverse correlation between the number of years of exposure and the drop in FVC, FEV1 and FEF 25-75%, while a multiple linear regression analysis which included these three spirometric variables and the FEV1/FVC showed a correlation only between the FEV1 and the number of years of exposure. However, the study in the communities of Cutini Capilla in Puno and Ayamachay and Uyshahuasi in Inkawasi, Lambayeque found that the ratio FEV1/FVC, which is a measure of

obstruction of the airways, fell significantly as the number of years' exposure to biomass fuels increased (Figure 5).

Fig. 5: between years of exposure to wood smoke and FEV1 / FVC



The team from the *Instituto de la Altura* (Highlands Institute) of Cayetano Heredia Peruvian University also evaluated members of the communities of Cutini Capilla in Puno and Ayamachay and Uyshahuasi in Inkawasi, Lambayeque, for oxygen saturation and gases in the blood and found that partial pressure and oxygen saturation decreased with time of exposure to biomass fuels (Figures 6 & 7).

Fig. 6: Ratio between exposure time to wood smoke and pO_2

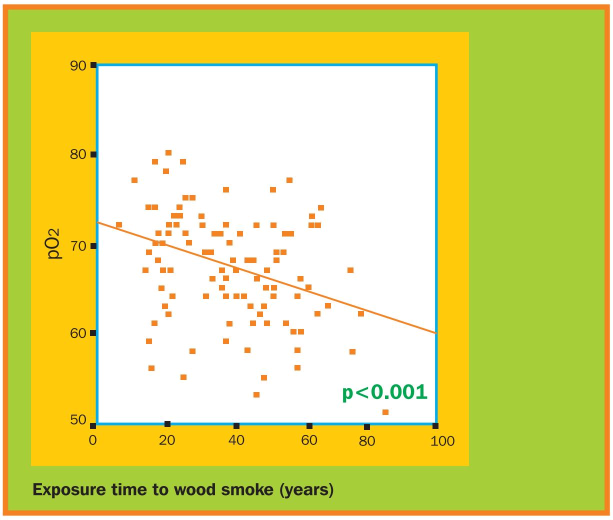
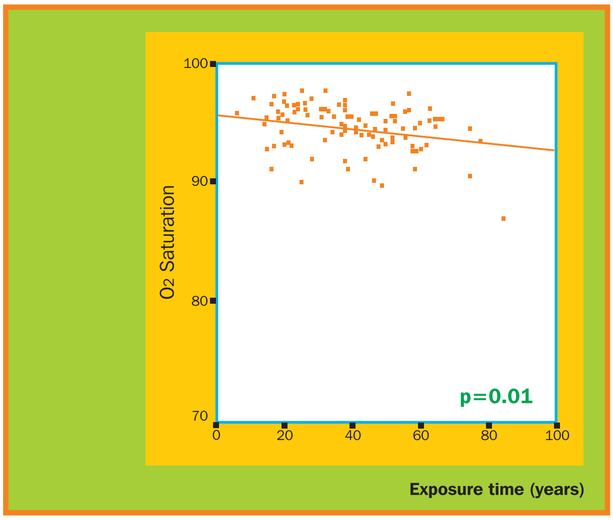
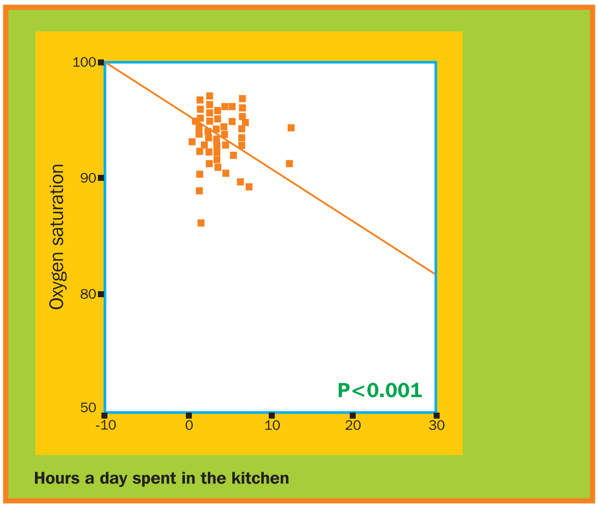


Fig. 7: between exposure time to wood smoke and O_2 saturation



Furthermore, oxygen saturation diminished with time spent in the kitchen (Figure 8).

Fig. 8: Ratio between time in the kitchen and blood oxygen saturation



One of the most interesting pieces of research carried out by the team from Cayetano Heredia Peruvian University was the control case study which included 46 cases and 46 controls, matched by age, sex, ethnicity, place of birth, marital status, level of education and occupation. The cases were patients with lung cancer that had been hystopathologically confirmed. In the controls, cancer had been discounted by clinical history and chest X-rays.

The odds ratio corrected for logistic regression was 5.11 for those exposed to biomass fuels, 6.59 for smokers and 3.78 for those who had a family history

of malignant cancers. A linear correlation was also found between the number of hours-years' exposure to biomass fuel smoke and lung cancer, with a Spearman coefficient of 0.36, $p<0.01$.

We now know, from all the studies carried out in different countries, that there are several categories of illnesses that may be due to exposure to biomass combustion:

These are chronic obstructive pulmonary disease (COPD) and cor pulmonale, secondary lung damage; cancer, particularly of the lungs and nasopharynx; acute respiratory infections, (particularly in children, because of a reduction in pulmonary defense mechanisms); tuberculosis; eye infections caused by irritation of the mucous membrane by smoke; low birth weight caused by the mother's exposure and associated with a range of prenatal and infant diseases; exacerbated bronchial asthma.

III.- A Successful Intervention: The Inkawasi Stoves

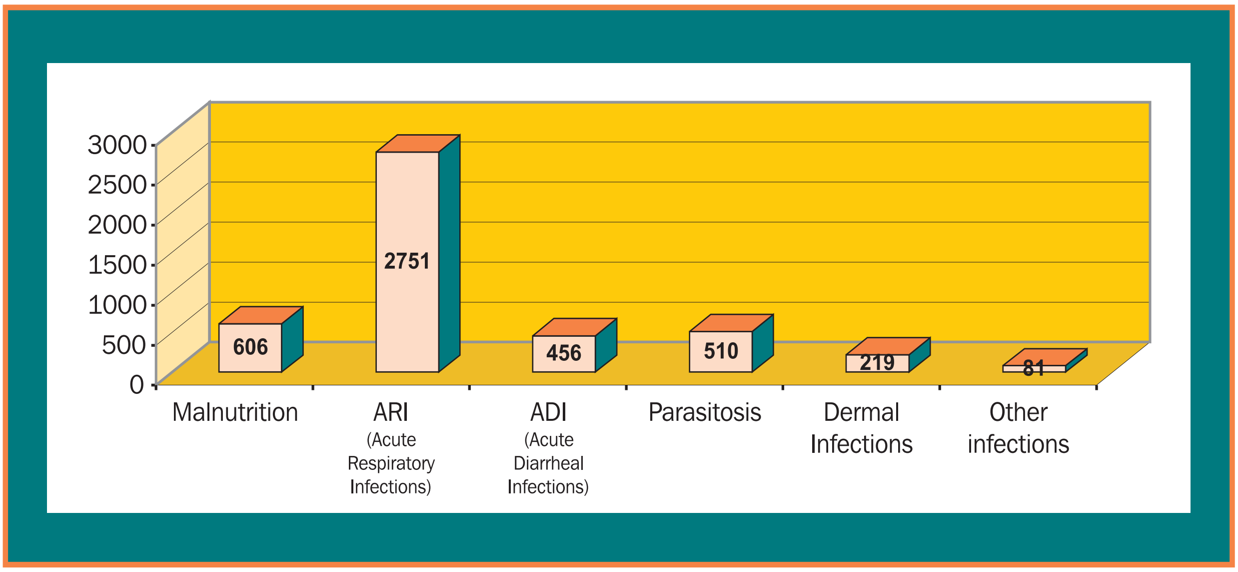
Pilot Program at Ayamachay:

Ayamachay, in the district of Inkawasi, is a typical village in the highlands of Lambayeque having some 60 households between 2600 and 3200 m.a.s.l. and approximately 350 Quechua-speaking inhabitants; the main occupation for the men is farming while the women look after their homes, gathering firewood, raising animals and helping in the fields.

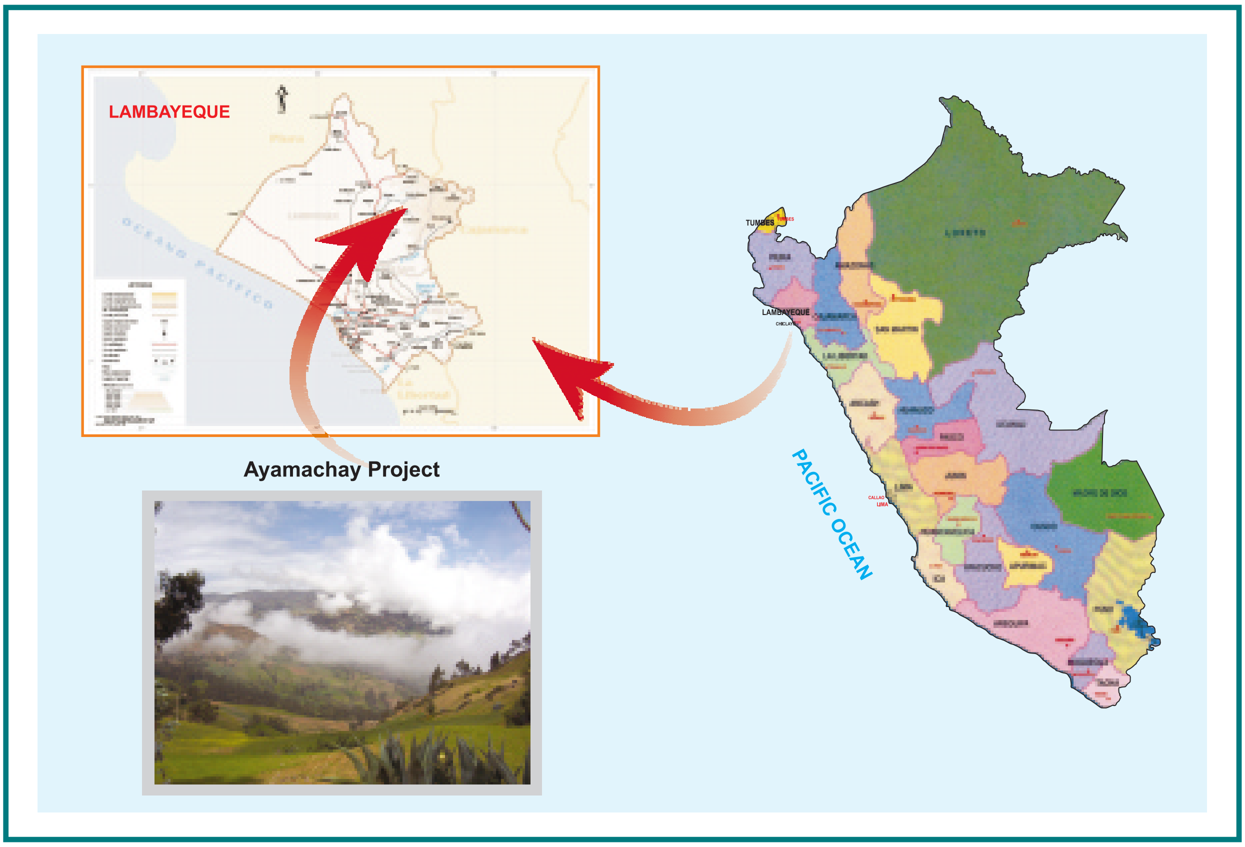
In 54% of households live children under the age of 5 and most of them are present when their mothers prepare food. All the houses have adobe walls, a beaten earth floor, a roof made of roofing sheets or adobe mixture and have bedrooms, dining room and other rooms apart from the kitchen. 92% of the houses have only tiny windows in the kitchen.

Acute respiratory infections (ARI) are the most frequent illnesses in the district.

Table 3:
Most frequent illnesses reported by health centers in the district of Inkawasi in 2004 - Ministry of Health (MINSA)



Location of the Pilot Project



The rainy season in this zone is between January and April; thus, access by vehicles is only feasible between May and December.

The objectives of the pilot project were;

- To improve the environmental health (concentrating on water and sanitation) of the population,
- Strengthen the ability of the population to help themselves,
- Design a successful and innovative methodology for replicating the project on a larger scale, as an example for projects with indigenous population, and
- Encourage joint working by the institutions in the Lambayeque region.

The components of the pilot project were;

- The creation of an informed demand for preventive measures to improve environmental health,
- Local development and participation in the construction of infrastructure (latrines, stoves, washing facilities, rehabilitation and extension of the drinking water system),
- Training on technical and administrative issues for the Drinking Water and Sanitation Services Board (JASS),
- Bilingual and intercultural sanitary education,
- Impact monitoring, and
- Raise awareness of the health sector.

The project had an intercultural and demand-based approach: Beliefs and practices concerning hygiene and water, diseases and their treatment were studied together with the target group. The development of strategies to modify and improve hygiene practices were based on this. As far as possible, the work was carried out in Quechua. The JASS was given a «virtual budget»: A fixed amount was assigned for the improvement of drinking water and sanitation conditions. The village could choose between different alternative technologies. The more the village was willing to give (materials, knowledge, labor, cash etc.) the more solutions they could «purchase». For example they could choose between one marble latrine or sixty prefabricated VIP latrines or sixty adobe latrines and water system extension while supplying local materials and labor. The stoves were part of a technology and infrastructure package (latrines, washing facilities, stoves, extension and refurbishment of the drinking water system) that has only been made possible by the commitment and effort of the locals. This infrastructure package was achieved with a budget that in other projects would have covered only latrines.

It should be pointed out that the subject of improved cooking facilities arose by accident; given that the majority of the houses are scattered and the project concentrated on drinking water and sanitation. In the process of examining what treatment techniques within the household could be improved or introduced to improve water quality, it was found that the most widely used and accepted method was boiling. It was during visits for interviews at home that the technical personnel found the amount of smoke in the kitchens unbearable and it was decided that the project should include the development of an improved stove with the following aims:

- To evacuate the smoke
- To increase the likelihood of boiling the water
- To save firewood
- Accessibility and economy based as much as possible in the use of local materials
- Satisfaction

Traditionally, the inhabitants of Ayamachay cook (or rather used to cook) in small ill-ventilated rooms with not much light, over an open fire set in a three stone hearth. In such an environment, the smoke is dense and aggressive and the walls and ceiling are covered with soot.

Procedure:

- Survey on local practices and preferences
- Development, comparison and validation of prototypes
- Building the stoves
- Monitoring.

Local practices and preferences:

The project's survey to determine current practices and preferences among the population of Inkawasi produced the following results:

1. During food preparation 45% were sitting on the ground, approximately 46 % used a bench or chair and almost 9% were standing.

2. As far as gathering firewood (biomass) is concerned,. In
36% of cases this is a family task, in 46% of households this is specifically a task for children or women, and in only 18% is it brought by men from the fields.

3. Pots and pans in which food is prepared are made of cast iron or aluminum.

4. The women usually spend 05 hours/day in the kitchen preparing food and eating, whilst the men remain there only 2.8 hours/day.

Development, Comparison and Validation of Prototypes

These results were used as a basis for choosing and developing five prototype stoves. There is a great variety of stove types around the world that comply the most important feature from a health's point of view: reducing indoor air pollution. Here we limit ourselves to comparing the three we found most relevant: The Three Stone Hearth, the Ordinary Improved Stove used in rural Peru and the Inkawasi Stove.

Three Stone Hearth

The three stone hearth is the type of stove most frequently used in zones where wood is used as fuel. It consists of three stones (or adobe bricks) placed in a dry room to form an equilateral triangle such that between the stones is a space through which the wood can be introduced.

The distance between the stones depends on the size of the pot being used. Its advantage is that it can be used with pots or pans of any type or diameter. Combustion is incomplete and the smoke remains inside the house.

In the southern Peruvian Andes and on the Andean plateau a terracotta stove which shields the fire is widely used and in most cases the fuel used is animal dung. In this case also the smoke remains in the room.

Traditional three-stone hearth

The Inkawasi Stove

The Inkawasi stove consists of an elbow-shaped combustion chamber. Two pots can be heated simultaneously. The first pot is heated by direct contact with the fuel and the second is heated by the bypassing hot gases. Reducing rings can be used for different sized pots. It was inspired by the «rocket stoves» and «Estufa Justa» developed by the *Aprovecho Institute* in Central America.

Inkawasi stove

The Ordinary Improved Stove

The agriculture sector and various NGOs have been promoting a simple stove consisting of two rows of adobe bricks with a cover and chimney. This has the advantage that smoke is removed and large pieces of wood can be burned. Its disadvantage is that its performance is poor and wood consumption is high. In general we can say that in many cases it does not fulfill the purpose for which it has been promoted: to reduce wood consumption.

The ordinary improved stove

Comparative tests of the stoves

Tests carried out on the different models described above convincingly demonstrated that the power, efficiency and energy consumption of the Inkawasi stove were superior and after this model had been chosen by the community it was built on a large scale.

Table 4:
Maximum Power and Energy Efficiency Comparison between the different Stove Models in the Village of Ayamachay - Inkawasi

Model	Power (w)	Efficiency %	Wood consumption (Kg/h)
Three Stone Hearth	1144,00	16,27	1,608
Ordinary Improved Stove	1441,81	10,93	1,973
Inkawasi Stove	1876,70	28,19	1,367

Source: José Humberto Bernilla

Table 5:
Energy Consumption and Efficiency over 90 minutes at Low Power of the Different Stove Models built in the village of Ayamachay - Inkawasi

Model	Energy (Mj)	Efficiency %
Three Stone Hearth	18,1935	8,95
Ordinary Improved Stove	20,7126	5,90
Inkawasi Stove	13,7126	10,65

Source: José Humberto Bernilla


Testing a metallic elbow prototype as combustion chamber

Table 6:
Wood Consumption and Time to Prepare a Typical Dish using the Different Stove Models built in the village of Ayamachay - Inkawasi.

Modelo	Leña (Kg)	Tiempo (min)
Three Stone Hearth	1,300	61,00
Ordinary Improved Stove	1,300	50,00
Ayamachay Stove	0,700	35,00

Source: José Humberto Bernilla

Construction of the Inkawasi Improved Stove

The current design of the improved Inkawasi stove has been tested under local climate conditions and in accordance with local needs after a comparison with other models which determined that the improved Inkawasi stove is better adapted to local conditions. The response by users has been very positive: The demand was so great that we easily managed to cover more than 90% of households.

The cleanliness or purity of the air inside the kitchen is guaranteed by the efficient combustion, the proper size of the canals, holes and the chimney through which the combustion gases and particles are evacuated.

Component parts of the improved Inkawasi stove

The improved stove has the following component parts:

- **Stove body.-** this is the base structure upon which the different components of the stove are installed, basically made from adobe and earth.

- **Combustion chamber.-** this is a ceramic elbow 12.7 cm internal diameter, 30.50 cm long and 30.50 cm high, made from refractory clay with a covering of dry ash (10 cm approx.) as a low cost insulator.

- **Concrete platforms.-** serve as a base for the pots; the improved Inkawasi Stove has two small platforms on different levels.

- **Chimney.-** the purpose of this component is to ensure an adequate draught in the combustion chamber and to evacuate the smoke effectively; the top is fitted with a windprotector to prevent

air-flow inversion. It may be made of steel, concrete or adobe.

This improved stove is built from simple local materials (adobe, earth, etc.) and cement. It is easy to light, does not go out easily and pots can be handled without difficulty; it has two potholes, one of which is located over the combustion chamber, which consists of a 90º elbow made of refractory clay, 5" in diameter and 12" high, it is installed vertically and has a layer of ash as a thermal insulator before being surrounded by adobe cemented with earth, to produce the stove body; the horizontal part of the elbow is divided into two sections by a metal plate enabling the fuel to be placed in the upper section while the inferior part enables air to enter and ensure complete combustion.

The heat is transmitted directly to the first pothole; the hot gases heat a second pothole before flowing to the chimney. A concrete platform is used to support the pots.

The stove is safe as there is no danger of fire or burns because the combustion chamber is very well insulated and the height of the stove is adequate for the women of the zone; the metal chimney is covered with earth and extends beyond the kitchen roof to a height equal to or greater than 75 cm. The stove generates 1800 W and achieves an efficiency of 28%.

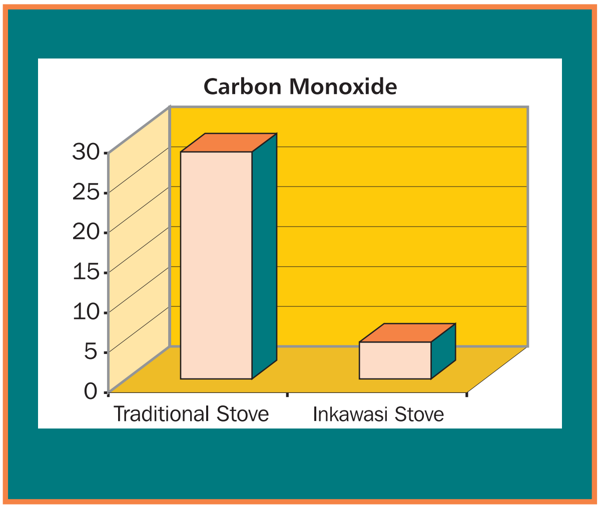
Use of the heat means that the second pothole can be used for pots of water so that boiled water that is safe to drink is always available to the benefit of health, bearing in mind that the majority of communities do not drink potable water. Families will also have hot water for washing, which is an important consideration given the cold weather in the area.

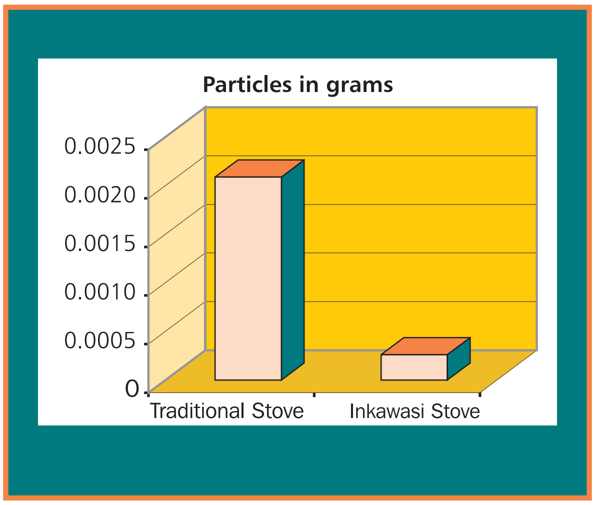
Cost of materials from outside the area: concrete platforms, chimney and combustion chamber: around S/. 50.00 (at present equivalent to 15.50 USD) per unit. Total direct costs, including transport, training, supervision, local materials and labor is estimated at S/. 110.00.

Significant Improvements with Environmental and Health Indicators

If the design of the Inkawasi stove is well built and operated, levels of contamination inside the households are significantly lower than those obtained when using traditional cooking methods. Figures 9 and 10 show that levels of carbon monoxide and particulate matter are several times lower when the Inkawasi stove is used.

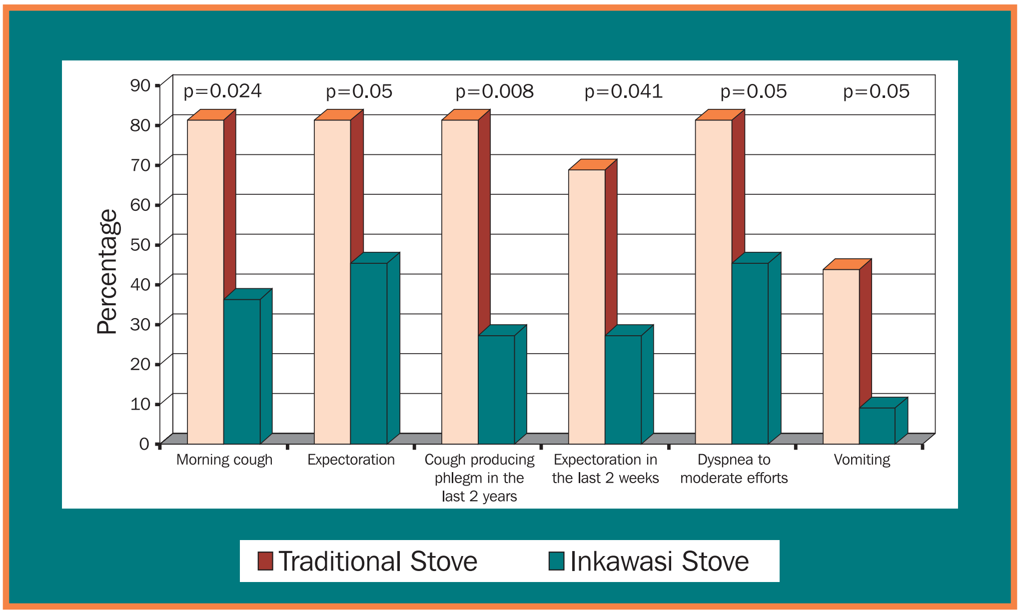
Figures 9 & 10
Comparative Measures of Gas Levels with Different Types of Stove





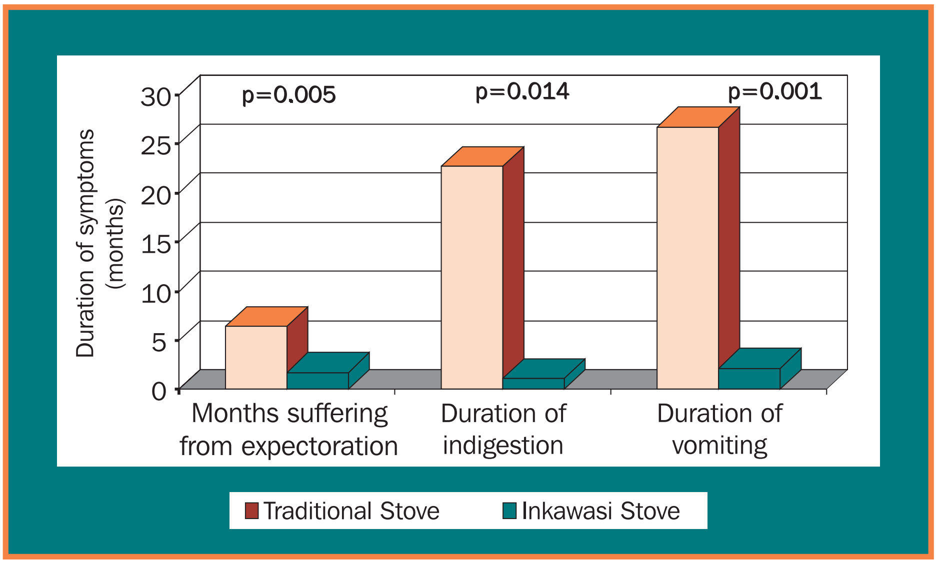
Continual exposure to biomass fuel smoke produces structural changes in the lungs, found by Accinelli to be visible in guinea pigs after only one year living under wood burning stoves in the central highlands of Peru. Recuperation is slow: When a person has reduced his exposure to biomass pollutants, e.g. when we improve the design of the stove, observable positive clinical changes may require years to become evident.

Figure 11: Symptoms occurring in those under 30, by type of stove



To determine whether the new biomass burning stove relieves respiratory symptoms, Accinelli examined people under 30 years of age. We chose this group only because we considered that older people would have structural changes that would make a reduction in symptoms impossible in only a few months after adopting the Ayamachay model. The results were impressive (Figures 11 & 12). Some symptoms were present in almost two thirds of inhabitants and their duration also decreased significantly just as months of expectoration fell from 6.4 to 1.75. (p=0.005)

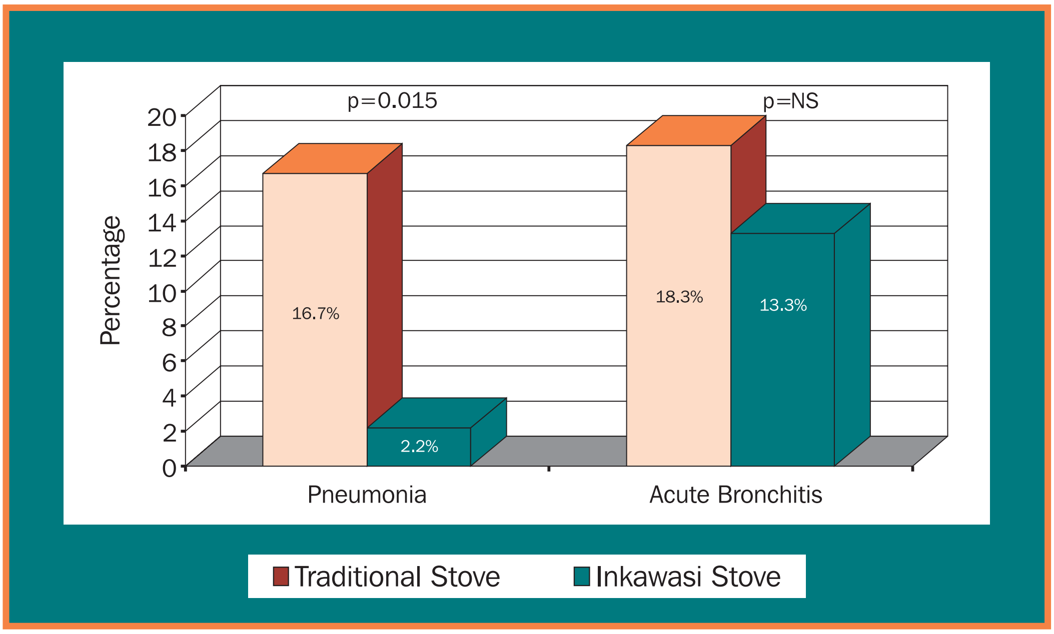
Figure 12: Duration of symptoms in inhabitants under 30, by type of stove.



Accinelli also found that respiratory infections were fewer when the Ayamachay stove was used (Figure 13). The percentage of people who claimed to have had pneumonia was almost 8 times less among those using the Ayamachay stove.

The new model, therefore, not only produces less contamination but it benefits the health of those who cook using biomass fuels.

Figure 13:
Frequency of respiratory infections among users of both types of stove



lthough biomass fuels contaminate more, they also usually cost less. This means that in most of rural Peru they cannot be replaced in the short or medium term by others less damaging to health.

Clean fuels such as gas are products of the market; whilst wood for the people in rural Peru does not imply a monetary cost, but time and labor collecting and cutting it.

At present, the only economic and socially possible solution is the construction of new models of biomass fuel stoves that are more efficient and which, as they have chimneys, remove contaminants from the room used as a kitchen.

Construction and assembly process

Construction of the Stove Body.

Construction employs the following materials: adobe and earth.

A platform is built 55 cm wide and 1.00 m long by 35-40 cm high. The platform is then increased to the following dimensions: 55 cm wide, 57 cm long and 35 cm high. With the body in the form of steps, construction is completed by erecting two walls parallel to the length of the stove but laying the adobes on edge to make a space in which the combustion chamber will be installed.

Manufacturing and Installation of the Combustion Chamber.

The combustion chamber can be made locally using refractory clay. This type of combustion chamber consists of an elbow 12.7 cm in internal diameter, 30.5 cm long, 30.5 cm high and 2.5 - 3 cm wall thickness, and it is installed as follows:

The ceramic elbow is placed in the form of an L in the central part of the space in the body, leveled horizontally and vertically and the space between the walls and the elbow is filled with ash (thermal insulation) and on the part of the ceramic elbow that is level with the body an adobe wall is built, taking care that it does not rest on the ceramic elbow; continue to fill with ash up to 2.5 cm below the upper mouth of the ceramic elbow, finish sealing with ash leaving a flat surface level with the upper end of the elbow.

Construction of apertures and tunnels.

For this work the following materials are needed: 1.60 m smooth iron bar 12.7 mm in diameter cut into 4 pieces 40 cm. long, earth and moulds for the apertures.

The mould for the apertures of 29 cm in diameter is placed on the flat surface of the upper part of the combustion chamber concentric with the mouth of the ceramic elbow; the outer part of the mould is filled with earth to a height of 2.5 cm, the mould is removed and 2 pieces of steel are placed parallel to the axis of the stove, separated by the diameter of the ceramic elbow, kept level as they will support the cooking pots; the mould is again put in place and filled with earth to a height of 6 cm, left to dry a little and the mould removed; a channel is then made towards the second pothole, having the following dimensions: 10 cm wide, 6 cm high and 7 cm long.

The rest of the structure is filled with earth up to the level of the bottom of the channel and the second pothole is built in the same way as the first, finishing with a channel of the same dimensions as the first one, but at an angle to a line joining the two potholes, so that when the chimney is installed it is near to the wall (away from the operator) thus avoiding burns.

Construction and Installation of the Concrete Slab.

The concrete slab requires the following materials:

5 Kg. cement, ½ bucket of gravel, ½ bucket of sand, 6 m. reinforcing bar, 20 cm Nº 16 galvanized wire.

Place a sheet of paper or plastic on a flat surface to prevent the concrete adhering to it, erect timber shuttering and place the aperture moulds in their respective positions; pour the mixture and install the reinforcing bar, continue pouring until a smooth surface is obtained level with the shuttering.

Leave to cure for at least 2 hours and remove shuttering and moulds.

The diameter of the apertures for the cooking pots is 25 cm and the hole for the chimney is 7.6 cm in diameter, the thickness of the slab is 3 cm by 50 cm wide and 43 and 55 cm long, respectively.

They are installed after 5 days, during which time water should be sprinkled on them to ensure correct curing.

To install the slab, place a very thin layer of earth on the flat top of the structure, install the first slab for the first pothole ensuring that it is centered and leveled, and then install the second slab in the same way. The difference in level between the first and second slabs must be approximately 8 cm. And the slope between the two slabs is 75º.

Preparing and installing the chimney.

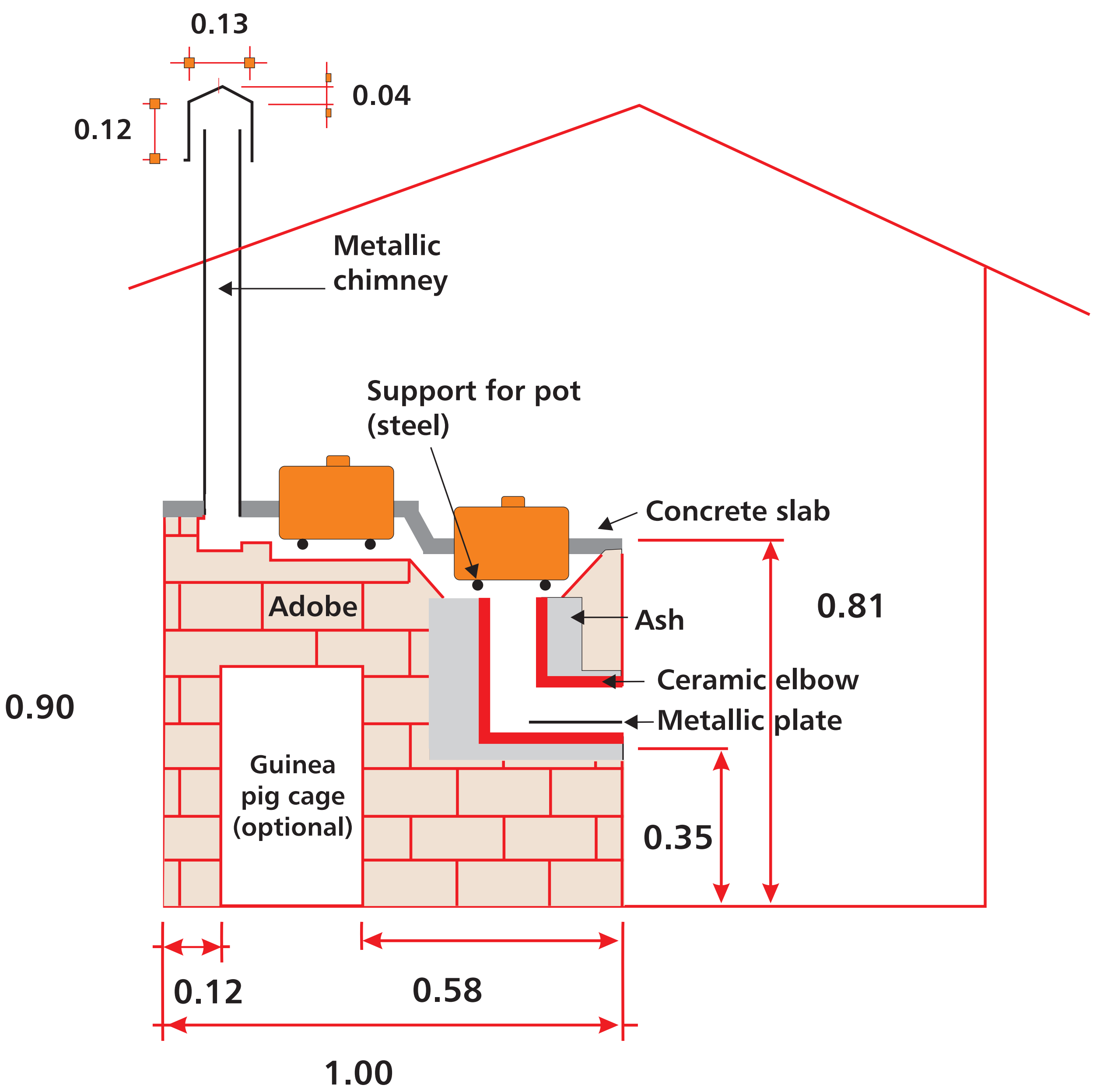
Remove the grease covering the electro-welded pipe and paint pipe and protector with rust-proof paint, allow to dry and assemble the pipe and protector using the Nº 16 galvanized wire, install as follows: with the aid of a plumb line align with the chimney aperture and mark where it will pass through the roof, make a hole the size of the chimney in the roof and introduce the pipe from above fitting it to its respective aperture and securing it well to the slab and the roof, then cover the lower part with earth to prevent burns.

After all this has been done check the entire installation and finish off those parts that require it, place a rectangular metal plate 1/8" thick, 12 cm wide and 20 cm long in the horizontal part of the ceramic elbow so that fuel can be introduced above it and air enter beneath it thus ensuring a good distribution of air through the wood fuel.

If the pieces of wood are large, a support can be placed facing the side where fuel is introduced so that the wood does not fall on the floor. The stove is now ready to be lit and tested.

Figure 14:

Sketch of the Inkawasi stove



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The GTZ-PAHO/WHO Project "Improvement of Environmental Conditions (Water and Sanitation) in Indigenous Communities"

In 1999 the Panamerican Health Organization PAHO and the German Agency for Technical Cooperation GTZ joined efforts to improve access to and quality of drinking water and hygienic conditions in indigenous communities in Latin America. The project was coordinated by PAHO´s Panamerican Center for Sanitary Engineering and Environmental Sciences and the GTZ in Lima. National Task Forces (NTF) in 15 countries were established to develop and implement methodologies to improve Environmental Health Conditions in Indigenous Communities. These NTF had an interinstitucional and intercultural approach bringing together representatives of health and drinking water authorities with indigenous organizations, NGOs and universities.

The NTF of Peru implemented a total of 4 pilot projects in the Andean Highlands and the Amazon Basin. In this publication we will take a closer look at the pilot implemented in Ayamachay, a quechuaspeaking community in the Northern Sierra of Peru where the prototype of the "Inkawasi Stove" was developed.

THE PROBLEM

In the rural Andean highlands the vast majority prepares food using indoor open fires. Due to climatic conditions, the rooms used as kitchens have almost no ventilation and thus exposition to Indoor Air Pollutants is elevated. In many cases the indoor concentration of smoke, particular matter and gases are ten, twenty and even more times above those recommended by the World Health Organization (WHO). This takes a considerable toll on health, producing chronic obstrucive pulmonary diseases (COPD) and favouring Acute Respiratory Infection (ARI) and other respiratory illnesses. Respiratory illnesses are the single most important health problem in the Peruvian Andes.

THE RELEVANCE

This situation is a daily reality for more than 9 million Peruvians alone, who share these conditions with many often poor and/or indigenous Bolivians, Ecuatorians, Colombians, Venezolaneans and Chileans.

A SOLUTION

One approach could be improving rural health services to deal adequately with the symptoms, but obviously it is preferable to remove or minimize if possible- this key factor of respiratory diseases.

The substitution with cleaner fuel is illusory in the short and medium run. Clean fuels such as gas are market economy products; whilst cash is a extremely scarce ressource in these regions characterized by subsistence agriculture with barter economy elements. Fuel wood for the people in rural Peru does not imply a monetary cost, but time and labor collecting and cutting it.

At present, the only economic and socially possible solution seems to be the implementation of improved stove programs that remove contaminants from the rooms used as kitchens.

The Inkawasi Stove presented in this publication seems to be appropiate for the setting it has been developed for. It consists of adobe bricks, a ceramic combustion chamber, dry ash for insulation, concrete platforms and a steel chimney. The first of two potholes is fired directly while the second is heated by the hot gases on their way to the chimney. The Inkawasi Stove has proved to be an economic and efficient solution. Given the participation of the locals with manpower and local material such as adobe bricks, the cost in material is about 16 USD.

A year after implementation investigators from the Caetano Heredia University concluded that Indoor Air Pollution is reduced resulting in a significant positive health impact with a considerable decrease in symptoms of respiratory illnesses.

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